B. Observations are consistent with the hypothesis that ovulation occurs in the late summer to early autumn, and that residual small follicles in the ovary enlarge during the succeeding 12 months, reaching a mature diameter of 5-7 mm. in the middle of the following summer.

C. Philipp (1958) collected 15 mm. *Myobatrachus* in August and suggested that these froglets hatched from eggs fertilised 3-4 months previously. The yearly growth cycle data presented here support this suggestion. As ovarian enlargement may be commenced at a body length of between 30 and 40 mm. a period of at least two years probably intervenes between hatching and the first ovulation.

V. ACKNOWLEDGMENTS

The authors wish to thank Dr. W. D. L. Ride and Dr. G. F. Mees, of the Western Australian Museum, for permission to examine the series of *Myobatrachus,* and Dr. A. R. Main, of the University of Western Australia, for reading the manuscript. The study was carried out during the tenure of research grants from the University of Western Australia.

VI. REFERENCES

BHADURI, J. L., 1953. A study of the urino-genital system of Salientia. *Proc. Zool. Soc. Bengal,* 6 (1): 1-111.

CALABY, J. H., 1956. The food habits of the frog, *Myobatrachus gouldii* (Gray). *W. Aust. Nat.,* 5 (4): 93-96.

FLETCHER, J. J., 1898. Contributions to a more exact knowledge of the geographical distribution of the Australian Batrachia No. V. *Proc. Linn. Soc. N.S.W.,* 22 (4): 660-684.

GLAUERT, L., 1945. Some Western Australian frogs. *Aust. Mus. Mag.,* 8 (1) 379-383.

HARRISON, L., 1927. Notes on some Western Australian frogs, with descriptions of new species. *Rec. Aust. Mus.,* 15 (4): 277-287.

MAIN, A. R., M. J. LITTLEJOHN & A. K. LEE, 1959. The ecology of Australian frogs. In *Ecological Research in Australia,* Ed. F. S. Bodenheimer. W. Junk: The Hague.

NOBLE, G. K., 1931. *The Biology of the Amphibia.* McGraw Hill: N.Y. and Lond.

PHILIPP, G. A., 1958. *Myobatrachus gouldii* in the coastal hills near City Beach. *W. Aust. Nat.,* 6 (5): 131-132.

CATASTROPHIC DESTRUCTION OF THE LITTORAL FAUNA AND FLORA NEAR FREMANTLE JANUARY 1959

By E. P. HODGKIN, Department of Zoology, University of Western Australia, Nedlands.

INTRODUCTION

In late January 1959 there were exceptionally low tides on the coast near Fremantle. The Harbour Trust gauge was out of order during this period, but visual observations there were within $\pm$ 0.05 ft. of those recorded at Rottnest (table 1). Mean low water for

January is 1.3 ft. (1949-58), levels of 0.5 ft. or less have been recorded on only 24 days in the last ten years, and levels of 0.3 ft. or less were last recorded in December 1947 (reaching zero on 30th and 31st).

TABLE 1.—TIDE LEVELS AND MAXIMUM SHADE TEMPERATURES AT ROTTNEST

	Feet above Fremantle datum		Temperature
January	Low water	High water	degrees F.
23	0.7	2.8	72
24	0.5	2.5	73
25	0.1	2.2	74
26	0.3	2.2	78
27	0.5	2.0	84
28	0.9	2.2	102

On the four days 24th to 27th water level was below the one foot mark from before dawn until after 3 p.m. The sea was very calm on 24th to 26th, the small waves barely lapped the outer edge of the reef platform (as seen at Cottesloe) but on 27th there was more water movement (at Yanchep). Temperatures were not excessive until 27th and 28th. Morning winds were mainly southerly on 23rd and 24th, S.E. on 25th and 26th, E. on 27th, and N.E. on 28th; the usual S.W. winds followed in the afternoons.

The intertidal limestone platforms of the vicinity of Fremantle are at various levels, but few are less than 1 ft. or more than 2½ ft. above datum. During the above periods of low tide all except the lowest of these "reefs" were exposed to drying throughout the heat of the day for several successive days, or where shallow water was retained on them it stagnated and must have become very hot. Only the extreme outer edges of the platforms were periodically refreshed, by the very small waves.

The effect on the animal and plant life was catastrophic. Vast numbers of animals were killed and lay rotting on the reef platforms for weeks afterwards and the sea weeds suffered great damage.

OBSERVATIONS

Only two reefs were visited during the period of low tides and the full extent of the damage was not appreciated until Rottnest Island was visited on February 9 to 19.

At Cottesloe a low level platform (less than 1 ft. above datum) south of Mudurup Rocks is covered by coralline algae *(Jania)*. The chief casualties here were the small starfish *Patiriella* and a small sea slug; both were dying in large numbers on January 26. On the lower part of the Yanchep reef (January 27) *Patiriella* again suffered heavily and many recently dead specimens of the following were found: crinoids, ophiuroids, echinoids *(Heliocidaris, Holopneustes, Phyllacanthus)*, asteroids *(Coscinasterias, Pentagonaster)*, worms, shrimps, crabs, small fish, *Clavarizona* and other chitons, the fissurellids *Macroschisma tasmaniae, Amblychilepas javanicencis* and *Scutus anatinus, Quibulla* sp., the lamellibranchs *Pinna dolabrata* and *Electomactra antecedens*. Mr. G. Kendriek who kindly supplied the above list also noted small numbers of other species and remarked on the abundance and sluggish condition of others,

particularly *Floraconus* and *Dyraspis*. This was in the early morning so that the mortality observed must be attributed to the heat of the previous days. *Haliotis roei* is particularly abundant on the edge of the platform here but there was no mass mortality although some recently dead specimens were found.

At Rottnest there was still abundant evidence of recent devastation two to three weeks after the low tides. Mortality was heaviest on platforms at North Point, round Cape Vlamingh at the extreme west end, and on the radar station reef on the south side of west end. Salmon Point and Green Island reefs suffered relatively little damage.

The outermost part of all these platforms, where waves normally break continuously, are thickly encrusted with coralline alga (lithothamnion) over which graze the following molluses: *Onithochiton occidentalis, Clavarizona hirtosa, Poneroplax costata, Haliotis roei, Patellanax laticostata, P. peroni,* and *Patelloida alticostata;* the large barnacle *Balanus nigrescens* is also common. On the southern extremities of Radar reef (at + 2.5 to + 2.8 ft.) and the Cape Vlamingh reef (at a similar height) all these animals were still present, but large numbers of shells, empty or with the decomposing animals still in them, had accumulated on the inner part of the platforms and testified to the destruction that had taken place. Large *Balanus* shells stood empty in situ, some with the remains of the animal still present. At the extreme western end of the Cape Vlamingh reef a ridge rises to 4 ft. above datum. This is rarely accessible, but when visited some years ago by L. M. Marsh it had a very dense population of *Onithochiton, P. laticostata,* and *Balanus* over the encrusting lithothamnion. On February 18 almost all the *Onithochiton* and *P. laticostata* had disappeared from the upper part of the ridge and its landward face and the rock was covered with a new growth of blue-green algae. The *Balanus* shells were empty.

Immediately behind the outer fringe, at both Radar and Cape Vlamingh reefs, there is a belt of "limpet gardens" dominated by large *P. laticostata.* Few of these limpets survived, their empty "homes"* showed up prominently and a dense felt of filamentous blue-green algae covered the ungrazed rocks, with a few *Siphonaria luzonica* and *P. alticostata* cutting tracks through it.

Part of the wide reef to the north of Cape Vlamingh and part of North Point reef are bordered by platforms 10 to 20 yards wide and 3 to 3½ ft. above datum. When visited on previous occasions these had a thin cover of lithothamnion, a dense population of *P. alticostata* (up to 250 per sq. yd.) and smaller numbers of *Actinia tenebrosa, Clavarizona, Onithochiton. Poneroplax,* the mussel *Hormomya,* and colonies of the zoanthid *Palythoa heideri.* The only animals that survived were those within a yard or two of the outside edge, and *Actinia* in small pools. At North Point three other limpets had also been killed: *Patellanax peroni, Notoacmaea onychitis,* and *Siphonaria luzonica.*

* The sites to which limpets return regularly when the tide falls. These show up clearly when the animal is removed from the rock.

The north Cape Vlamingh reef is about 75 yards wide and some 600 yards long. Much of this lies at about + 2 ft. and does not retain water at low tide. Previously this was colonised by *P. alticostata,* almost alone, at a density of about 150 per square yard; very few survived and over a million must have died here.

On the south side of the Cape, behind the limpet gardens, there is an area (at about + 2 ft.) with sparse weed growth and extensive colonies of the zoanthids *Palythoa densa, P. heideri,* and the coral *Pocillopora damicornis.* Most of these colonies was dead. On a similar area at Radar reef they had suffered less severely. *Pocillopora* and several species of Zoanthid are common in pools in the platforms at Cape Vlamingh and at Salmon Point. The colonies were bleached white to the level to which water must have been retained; below this they were unaffected.

Also to the south of the Cape and close to the cliff is a high (+ 3 ft.) part of the reef that is normally wave-swept. This had previously had a large population of the urchin *Echinometra mathaei,* each urchin in its characteristic burrow. None had survived, and the burrows lay clean and empty. Part of the north platform at + 1.5 ft. always retains water. The abundant *Echinometra* here did not appear to have suffered; however, many of the large *Tripneustes gratilla* that also live here had been killed and were still rotting on the reef. There was also a high mortality among the only other population of *Tripneustes,* on the inner part of Radar reef. Considerable numbers of a third urchin, *Heliocidaris erythrogramma* had been killed on the outer part of Parker Point reef; some *Echinometra* had also been killed here.

A high mortality of one other sedentary animal was also noted. On the inner part of North Point reef there are large colonies of the mussel *Hormomya,* normally just at water level on the deeply pocketed platform (at + 2 ft.). Almost all the animals were dead.

Not only had the sedentary and semi-sedentary animals of the platforms been killed but many of the more actively moving had also died. Large numbers of empty shells of *Senectus intercostalis (= pulcher), Dicathais aegrota,* and *Ravitrona caputserpentis* strewed Radar and Cape Vlamingh reefs. At North Point small numbers of the following were picked up apparently dead: *Ninella whitleyi, Mayena australasia, Dyraspis doreensis, Floraconus* sp., *Campanile symbolicum, Vertagus asper,* and *Quibulla* sp.

It was also reported that at the time of the low tides large numbers of many kinds of reef fish, up to a foot long, died on the platform. Dead and dying crayfish *(Panulirus longipes)* were picked up, dead octopus and many "sea slugs" were also seen.

It is more difficult to assess damage to the algae. On the north Cape Vlamingh reef large quantities of the coralline *Jania* were washed up on the beach. Here also the dominant algae on part of this reef (at + 1.5 ft.) are *Cystophora* and *Sargassum;* these had been killed back almost to the holdfasts and were covered with a heavy growth of *Hydrocoleum glutinosum.* On the outer edge of North Point reef (at + 1 ft.) only the bare stalks of *Cystophora retroflexa* remained.

Above the level of the platforms there had been no such catastrophic mortality. *P. alticostata* usually dominates the lower 1 to 2 feet of the undercut cliff. In many places there was a line of empty "homes" at the top of this zone, but rarely any general destruction. Above this *Notoacmaea onychitis* and *Siphonaria luzonica* are the dominant organisms. Again there were empty "homes" but no large scale recent denudation, nor was there any evidence of mass destruction of the littorinids *Melaraphe unifasciata* and *Tectanus rugosus* of the supralittoral.

DISCUSSION

Certain anomalies in the observed mortality may be noted here. The survival of *Patelloida* on the steep slope of the undercut while those on the platform below died may perhaps be explained by the different angle presented to the sun, and the fact that the rock is often shaded for part of the day. However, it was surprising to find *Patellanax laticostata* surviving in a similar situation (Green Island and Parker Point) since the favoured habitat of this species is the outer part of the platform consistently washed by the waves. Also it is difficult to understand why there should have been total destruction of *Patelloida* over most of the Cape Vlamingh platforms while there was no significant mortality on the Green Island and Salmon Point reefs which are at practically the same level (1.5 ft.), on a part of the North Point Reef which is even higher, or at Yanchep.

Mortality among intertidal organisms near the top of their normal vertical range is an annual event. During winter the higher sea level, almost continuous wave action, and lower temperatures allow plants and animals to establish themselves above the level at which they can survive in summer. This is particularly noticeable in the intertidal undercut where a variety of green and blue-green algae and the sporelings of brown and red algae establish themselves each winter, only to be killed off with falling sea level and calm seas about September.

Each summer the empty "homes" of *Notoacmaea* can be found and on hot days limpets which have strayed too high are seen dying. *Patellanax laticostata* are sometimes found dying on hot days, even when waves still lap them. Survivors from the January catastrophe were dying on the edge of the platform on February 19 when the sea was again very calm. On the granite rocks of the south coast of Cape Naturaliste large numbers of young *Balanus* that have settled too high have been found dead in early summer.

This annual mortality is doubtless a potent factor in maintaining the characteristic shore zonation. The catastrophic mortality recorded above is however of quite a different order, nothing like it has been seen here in the last ten years. Destruction on this scale must nevertheless recur from time to time when very low tides and calm seas combine to prevent water from flowing over the platforms throughout the heat of several successive days. It is a natural phenomenon with which the organisms have come to

terms; it may, however, radically change the distribution of particular organisms on the platforms from time to time.

One can only speculate about how long it will be before the previous associations are re-established, if at all. Experience with experimental removal of limpets indicates that many years may elapse before these animals again dominate some of the areas from which they have been eliminated, and other animals will doubtless take time to recolonise their habitats. This large scale natural experiment will be watched with great interest.

[Note: Relevant tidal data will be found in: Hodgkin, E. P., and V. Di Lollo, 1958, The Tides of South-Western Australia. *J. Roy. Soc. W. Aust.*, 41: 42-54. A short description of the Rottnest reefs and the intertidal fauna and flora will be found in: Hodgkin, E. P., L. M. Marsh and G. G. Smith, 1959. The Littoral Environment (of Rottnest). *J. Roy. Soc. W. Aust.*, 43 (in press).]

HERPETOLOGICAL MISCELLANEA

By L. GLAUERT, Western Australian Museum, Perth.

X.—DRAGON LIZARDS (FAMILY AGAMIDAE)

Small dragon-like lizards having the head covered with small scales and those on the body and limbs overlapping. Limbs with five digits, the anterior at times reduced but still functional. Tail long and occasionally as much as three times the length of the head and body, terminating in a fine point, can be replaced when lost but not shed. Teeth situated on the top of the jaw, not attached to the side as in the other families of lizards.

KEY TO THE GENERA

I. Body covered with normal scales.
  A. No preanal or femoral pores, no transverse gular fold, pouch in the male ..... *Chelosania*
  AA. Preanal pores present, transverse gular fold present or absent, no gular pouch.
    B. Tympanum hidden ..... *Tympanocryptis*
    BB. Tympanum distinct.
      C. Preanal and femoral pores at least in the males, body depressed ..... *Amphibolurus*
      CC. No femoral pores, body slightly depressed ..... *Diporiphora*
      D. Body compressed, toes denticulate laterally ..... *Physignathus*
      DD. Body compressed, neck with large frill ..... *Chlamydosaurus*
II. Body covered with large spines ..... *Moloch*

Chelosania brunnea Gray
Thick-headed Dragon Lizard

Head large, cheeks swollen, covered above with small rough tubercles. Nostril equally distant from the eye and the tip of the